~~DESCRIPTION~~Title of the Invention

TUNABLE HIGH-FREQUENCY FILTER ARRANGEMENT AND METHOD FOR THE PRODUCTION THEREOF

~~TECHNICAL FIELD~~BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to the field of radio-frequency engineering. It relates in particular to a tunable radio-frequency filter arrangement ~~as claimed in the precharacterizing clause of claim 1,~~ and to a method for its production.

A radio-frequency filter arrangement ~~such as this~~of this type is known, for example, from ~~US A~~ US PATENT NO. 6,147,577.

A single tunable dielectric resonator, in which the moving dielectric body can move linearly in the vertical or horizontal direction in a cutout in the dielectric resonator element is known, by way of example, from EP-A1-0 601 369.

~~PRIOR ART~~Description of the Related Art

Transportable radio link connections (LOS=Line of Sight) have been proven for rapid and flexible construction of wire-free communication networks, in particular in rugged terrain without a suitable infrastructure, and these operate in the frequency range of two or more GHz (for example 4.4 to 5 GHz; or 14.62 to 15.23 GHz). Appropriate filters, in particular bandpass filters, are required for signal processing within the transmission and reception

~~appliances~~ arrangements for such directional radio links, which filters are designed not only for individual frequencies but are automatically tunable and are distinguished by constant high Q-factors over the tuning range.

In addition to the essential electrical and radio-frequency characteristics, filters ~~such as these~~of these type must, however, also be producible at low cost, must have a robust design, and must be designed to be reliable in use and to be ~~space saving~~compact and ~~weight saving~~light-weight. Space (volume) and weight, in particular, are major factors for the mobility of the overall communication system.

In the past, in order to reduce the size of the cavities for filters ~~such as these~~of these type, solutions have increasingly been proposed which have a dielectric resonator element arranged in a cavity as the tunable basic element, whose resonant configuration can be varied in order to tune the filter. One such solution is described, by way of example, in ~~US A~~ US PATENT NO. 6,147,577, which was initially cited ~~initially~~. In this known solution, a first round dielectric disk (ceramic puck) is arranged in a fixed position as a resonator in each of the cavities of the filter. An identical second round dielectric disk is located parallel above the first, and can be raised vertically, and lowered again, relative to the first disk by means of an electronically controlled motor drive. The linear movement that is required for this purpose is produced by a digital stepping motor, whose rotary movement is converted to a linear movement by a complex threaded rod mechanism.

This known filter arrangement has various disadvantages: firstly, it is comparatively difficult to achieve the

comparatively high accuracy and reproducibility of the disk position during a linear movement of the moveable disk, as is required for good tunability of the filter. Secondly, the adjustment mechanism that is required for the linear movement requires a very large amount of space. As can easily be seen from figure 4 in ~~US A~~ US PATENT NO. 6,147,577, the motorized adjustment mechanism that is arranged above the cavities occupies about 2/3 of the entire physical volume of the filter. Furthermore, ~~owing~~ due to the capability of the upper disk to move in the vertical direction, the cavity must be initially designed to be comparatively large~~, from the start~~.

EP-A1-0 601 369, which was likewise cited initially, proposes a single tunable dielectric resonator in which an eccentric cutout is provided in the dielectric disk that is arranged in a fixed position in a cavity, which cutout can be entered to a greater or lesser extent by a dielectric body that is shaped to match the cutout. The resonator is tuned by adjustment of the insertion depth. For this purpose, the dielectric body can be moved linearly via a holder in the form of a rod in the vertical direction (Figure 1 in EP-A1-0 601 369) or in the horizontal direction (Figure 2 in EP-A1-0 601 369). No further details are stated about the tuning response that can be achieved by this solution. Furthermore, no mechanically ~~worked out~~ adjustment mechanism is specified either, so that this proposal should in fact be regarded just as paper prior art, and its feasibility is more than questionable. In particular, this solution proposal is also subject to the same disadvantages resulting from the linear movement as those which have already been discussed further above.

~~DESCRIPTION~~ SUMMARY OF THE INVENTION

One object of the invention is thus to provide a tunable radio-frequency filter arrangement which can be produced cost-effectively, is distinguished by a particularly compact and robust design with good radio-frequency characteristics, and has an advantageous tuning response, and to specify a cost-effective and simple method for its production.

~~The object is achieved by the totality of features in claims 1 and 27.~~ The essence of the invention is to provide, as a tunable filter module, a cavity with a dielectric resonator element which is arranged in a fixed position and has an eccentric cutout in which a dielectric body is arranged such that it can rotate. The arrangement of the body such that it can rotate in the cutout allows the dielectric resonator element to be designed to be extremely compact. The rotary movement can be designed with high precision, thus allowing high tuning accuracy and reproducibility to be achieved.

One preferred refinement of the filter arrangement according to the invention is distinguished in that the dielectric resonator element is in the form of a planar, round circular disk, and in that the dielectric body can rotate about a rotation axis which is at right angles to the disk plane of the dielectric resonator element, in that the dielectric resonator element has a predetermined thickness, and in that the dielectric body has a height in the direction of the rotation axis which is essentially equal to the thickness of the dielectric resonator element.

A development of this refinement has been found to have a particularly advantageous tuning characteristic, in which the cutout in the dielectric resonator element is a circular cylindrical through-hole which is concentric with

respect to the rotation axis, in which the external dimensions of the dielectric body are matched to the cutout in the dielectric resonator element in such a way that the two are separated from one another by only narrow air gaps, and the dielectric body is bounded by two parallel planar surfaces in a first direction at right angles to the rotation axis (60), and is bounded by two cylindrical envelope surfaces, which are concentric with respect to the rotation axis, in a second direction, which is at right angles to the rotation axis and to the first direction.

Undesirable interference fields in the dielectric resonator element and in the metallic cavity are preferably suppressed by the dielectric resonator element having a central through-hole.

It is also expedient for the dielectric resonator element and the dielectric body ~~each~~ to be each composed of the same material.

The filter arrangement has a particularly simple and compact design, overall, if, according to another development, the at least one filter is accommodated in a preferably rectangular filter housing, in that the filter housing is formed from a base plate and wall plates, which are at right angles to the base plate for the side walls, and is covered on the top face by a motor mounting plate, which is parallel to the base plate, and in that the cavities in the filter are formed by separating plates which are incorporated in the filter housing and are at right angles to the base plate, and mounting slots are provided in the base plate, in the wall plates and in the separating plates, by means of which the plates are plugged into one another and are connected to one another, in particular by being soldered. The electromagnetic

interaction of the cavities is in this case achieved in a particularly simple manner in that coupling openings, in particular coupling slots, are provided at predetermined points in individual separating plates.

Another development of the invention is distinguished in that a preferably circular opening is provided in the motor mounting plate above each of the corresponding cavities, through which the respective dielectric resonator element and the respective dielectric body are held in the cavity, in that the dielectric resonator element and the dielectric body are part of a tuning element which is associated with the cavity and is mounted on the motor mounting plate, and in that the tuning element in each case has a fixed holder, which passes through the opening in the motor mounting plate, for the dielectric resonator element, a holder which passes through the opening in the motor mounting plate and is mounted such that it can rotate, for the dielectric body, a motor, in particular a stepping motor, and a gearbox unit, which transmits the rotational movement of the motor to the holder, which is mounted such that it can rotate.

The arrangement is particularly ~~space saving~~compact if, according to one preferred development, the gearbox unit is accommodated in a housing, in that the housing is mounted on a motor mounting plate, in that the motor is flange-connected to the housing, and in that the holder for the dielectric resonator element is attached to the housing.

Particularly precise tuning is achieved in that the gearbox unit has a rotating element which is known in the form of a shaft, is mounted in a prestressed precision bearing and is firmly connected to the holder for the dielectric body, and in that the rotating element is driven by a drive shaft

within the gearbox unit via a gearwheel which is firmly seated on the rotating element, with the drive shaft being connected to the motor and engaging with the gearwheel via a worm gear, and in that the rotating element is prestressed in the rotation direction in order to overcome play, preferably by means of a spiral spring.

Furthermore, space can be saved by the gearwheel being in the form of a circle segment, rather than a complete wheel. A configuration such as this in the form of a segment with a segment angle of about 100° is completely sufficient to cover the entire worthwhile adjustment range of about 90° of the dielectric body in the cutout in the dielectric resonator element.

Particularly reliable tuning with high reproducibility is achieved in that, a controller, which has a control block, a memory and an input unit, is provided in the eccentric cutouts in the dielectric resonator bodies in order to control the rotation of the dielectric bodies, in that position sensors, in particular in the form of light barriers which are connected to the control block, are provided in order to determine the initial position of the dielectric bodies in the radio-frequency filter arrangement, and in that value tables are stored in the memory and associate an appropriate angle position of the dielectric bodies with a small number of selected frequencies of the radio-frequency filter arrangement.

One preferred refinement of the method according to the invention is distinguished in that the sheet-metal parts are silver-plated, and are soldered to one another by means of a silver solder, the sheet-metal parts have mounting aids, in particular in the form of crossing slots, mounting slots and mounting lugs which are matched to one another,

in that the sheet-metal parts are initially loosely plugged together by means of the mounting aids and the crossing slots, mounting slots and mounting lugs in order to form the filter housing, and the plugged-together filter housing is made mechanically robust by pushing the mounting lugs into the mounting slots, in that silver solder, preferably in paste form, is applied to the junction points between the plugged-together sheet-metal parts, and in that the plugged-together sheet-metal parts are heated, preferably in an oven, until the silver solder melts and flows into the junction points.

The production process is particularly simple and cost-effective if all of the sheet-metal parts of a filter housing are cut from a common metal sheet, which has not been silver-plated, by means of a cutting method, preferably by means of laser cutting, in such a way that the cut-out sheet-metal parts are connected to the remaining area of the metal sheet only by a small number of narrow webs, in that the metal sheet together with the cut-out sheet-metal parts is then silver-plated, in that the sheet-metal parts are detached from the metal sheet after being silver-plated, and are then used to construct the filter housing, in particular with the majority of the webs remaining at those points on the sheet-metal parts which are located outside the cavities when the filter housing is complete.

~~Further embodiments are specified in the dependent claims.~~

BRIEF EXPLANATION OF THE FIGURES

The invention will be explained in more detail in the following text using exemplary embodiments and in conjunction with the drawing, in which:

Figure 1 shows a perspective overall view of the filter housing (the filter box) of a radio-frequency filter arrangement according to one preferred exemplary embodiment of the invention for a total of three filters~~ which are arranged alongside one another and each have four cavities which are arranged in a square and are coupled to one another (the tuning units with the dielectric resonator elements and adjustable dielectric bodies have been omitted, for clarity reasons)~~;

Figure 2 shows the filter housing from Figure 1, in the form of a side view of the longitudinal face with the inputs and outputs of the three filters;

Figure 3 shows the filter housing from Figure 1, in the form of a side view of the transverse face;

Figure 4 shows a perspective view of a metal sheet, which is used as a wall plate for the transverse faces of the filter housing as shown in Figure 1, and has a transverse separating plate between the three filters;

Figure 5 shows the perspective view of a metal sheet which is used in the filter housing as shown in Figure 1 as a transverse separating plate with a coupling opening between the four cavities within each of the three filters;

Figure 6 shows the perspective view of a metal sheet which is used in the filter housing as shown in Figure 1 as a separating plate running in the longitudinal direction with coupling openings

between the front and rear cavities of all three filters;

Figure 7 shows the perspective view of the base plate of the filter housing as shown in Figure 1 with a large number of mounting slots, into which the lugs of the separating plates and wall plates as shown in Figures 2 to 5 can be inserted, and can be soldered.

Figure 8 shows the perspective view of a tuning unit with a motor, a gearbox unit, a dielectric resonator element and a dielectric body which can rotate;

Figure 9 shows the tuning element from Figure 8, in a view from underneath;

Figure 10 shows a longitudinal section through the gearbox unit of the tuning unit from Figure 8;

Figure 11 shows the perspective view of the gearwheel, which is in the form of a circle segment, from the gearbox unit shown in Figure 10;

Figure 12 shows the perspective view of the dielectric resonator element of the tuning element shown in Figure 8;

Figure 13 shows the perspective view of the dielectric body, which can rotate, of the tuning unit shown in Figure 8;

Figure 14 shows the fundamental arrangement of the cavities of a filter in a square according to the exemplary embodiment shown in Figure 1, and the

orientation of the associated dielectric resonator elements and bodies within the cavities, with respect to the coupling slots;

Figure 15 shows an alternative arrangement to that in Figure 14 of the cavities of a filter, in a row;

Figure 16 shows the outline circuit diagram of a control system for the radio-frequency filter arrangement according to the invention;

Figure 17 shows the arrangement and configuration of the sheet-metal parts for a filter housing as shown in Figure 1 on a common metal sheet;

Figure 18 shows the relationship between the filter frequency of the filter according to the exemplary embodiment and the rotation angle of the dielectric body 45;

Figure 19 shows the measured frequency profile of the S parameters S11 (reflection coefficient at the input; curve B) and S21 (transmission coefficient in the forward direction; curve A) of the filter according to the exemplary embodiment for the tuned frequency of 4.7 GHz over a frequency range of ± 15 MHz about the respective mid-frequency; and

Figure 20 shows the measured frequency profile of the S parameter S21 of the filter according to the exemplary embodiment, for the tuned frequency of 4.7 GHz over a wider frequency range of ± 60 MHz about the respective mid-frequency.

~~APPROACHES TO IMPLEMENTATION~~<u>DETAILED DESCRIPTION</u> OF THE <u>EMBODIMENTS OF THE </u>INVENTION

The tunable radio-frequency filter arrangement which is described in the following text has a filter housing (10 Figure 1) in which a number of tuning units (40 in Figure 8) are inserted and are screwed to the motor mounting plate (13 in Figure 1). The filter housing and the tuning units will be explained separately. The completely assembled filter arrangement is not illustrated, for reasons of clarity.

The rectangular filter housing (filter box) 10 illustrated in Figure 1 is composed of a thicker (at the top) motor mounting plate 13 and of a number of sheet-metal parts, which form the base, side walls and (inner) separating walls of the filter housing 10. The sheet-metal parts include the baseplate 11, which is illustrated individually in Figure 7, the wall plates 12 and 20 (see also Figure 4) which run in the transverse direction, the wall plates 14 and 32 (Figures 1, 2<u> respectively</u>) which run in the longitudinal direction, the transverse (inner) separating plates 15,..,19 which are illustrated individually in Figures 4 and 5, and the (inner) separating plate 33, which is located in the longitudinal direction and is illustrated individually in Figure 6. The sheet-metal parts are composed, for example, of 1 mm thick silver-plate sheet steel (material No. 1.4301). The motor mounting plate 13 is composed of the same material and is likewise silver-plated, but has a thickness of, for example, 4 mm.

As can be seen from Figure 17, the sheet-metal parts can be produced particularly easily and cost-effectively by cutting all of the sheet-metal parts of the filter housing 10 out of a common metal sheet 69 of suitable size, in the

manner illustrated in Figure 17. First of all, the metal sheet 69 is not silver-plated. Initially, the contours of the required sheet-metal parts 11, 12, 14,..,20, 32 and 33 are cut out in the metal sheet 69 by laser cutting and by a comparable cutting technique, with the sheet-metal parts that have been cut out still being connected to the rest of the metal sheet 69 at various points by narrow webs. The majority of the webs are arranged at points on the sheet-metal parts which are located outside the cavities 21,..,24 in the subsequent filter housing 10. The lack of any silver layer at these points means that there will be no affects on the radio-frequency characteristics of the cavities. Once the cut metal sheet 69 is in the form shown in Figure 17, a silver layer is provided over its entire surface. This results in the sheet-metal parts being virtually completely silver-plated. Such silver plating is missing only in the areas of the webs which will later be cut through. However, since these are largely located outside the cavities, this is not disadvantageous.

The filter housing 10 is formed from the individual sheet-metal parts 11, 12, 14,..,20; 32, 33 and the motor mounting plate 13 by soldering and pinning. The soldering is carried out by means of a suitable silver solder in an oven. The sheet-metal parts 11, 12, 14,..,20; 32, 33 are for this purpose first of all provisionally connected by plugging mounting lugs and mounting slots that are provided for this purpose into one another, and the sheet-metal housing that is formed is made mechanically robust by pushing the mounting lugs into the mounting slots. Only the wall plates 14, 32 on the longitudinal face of the filter housing 10 are pinned at the upper edge to the end faces of the motor mounting plate 11. A suitable amount of solder in the form of solder paste is applied to the junction points between the sheet-metal parts and is distributed such that

the gaps at the junction points are reliably closed during the soldering process. The housing that has been prepared in this way is then heated in an oven to the temperature required for soldering, and is cooled down again once the solder has melted and has run in the junction points.

In order to plug the sheet-metal parts 11, 12, 14,..,20; 32, 33 into one another, the baseplate 11 and the wall plates 14, 32 which are arranged on the longitudinal faces of the housing are , as shown in Figure 7, provided with a number of mounting slots 39 (some of which cross). The wall plates 12, 14, 20 and 32 and the separating plates 15,..,19 and 33 are equipped on their lower edges with mounting lugs L1 (Figures 4, 5 and 6) appropriate for this purpose, by means of which they can be plugged through the mounting slots 39 in the baseplate 11, and can be soldered. The transverse wall plates 12 and 20 and separating plates 15,..,19 additionally have mounting lugs L2 (Figures 4 and 5) on their side edges, which can be plugged through corresponding mounting slots in the longitudinal wall plates 14, 32, and can be soldered. In order to allow unimpeded crossing of the transverse wall and separating plates 12, 14,..,20; 32 with the longitudinally running separating plate 33, special crossing slots 34, 36, 37 and 38 (Figures 4-6) are provided in these sheet-metal parts. In this case, the crossings are alternate on the upper face and lower face (alternating crossing slots 37, 38 in Figure 6).

The longitudinally running separating plate 33 and the transverse separating plates 15,..,19 result in a total of 3 × 4 = 12 identical cavities, each with a square base area (A1~~,..,A4~~, A2, A3, A4 in Figure 7) being formed in the filter housing 10, four associated cavities of which are annotated, by way of example, with the reference symbols

21~~,..,~~,22, 23, 24 in Figure 1. The four associated cavities 21~~,..,~~,22, 23, 24 which are arranged in a square form a filter F3. In addition to the filter F3, the filter housing 10 shown in Figure 1 has two further identical filters F2 and F1 which likewise each comprise four cavities arranged in a square. Each of the filters F1, F2 and F3 as shown in Figure 2 has an associated input 26, 28, 30, and an output 27, 29, 31, respectively.

The four cavities of each of the filters F1, F2 and F3 are coupled to one another for radio-frequency purposes. This is achieved by means of suitably arranged, elongated coupling slots 35 in the transverse separating plates 15, 17, and 19 (Figure 5) and in the longitudinally running separating plate 33 (Figure 6). The coupling slots 35 are positioned in the present example such that they are located in the center of the wall of the adjacent cavity and on the vertical center plane of the cavities to be coupled. The importance of this position for the coupling characteristics will be described in more detail later. The transverse separating plates 16 and 18 which separate the filters F1, F2 and F3 from one another are, of course, not equipped with coupling openings.

A circular dielectric resonator element 44 (Figure 12) in the form of a disk is arranged in the center of each of the cavities 21,..,24 formed in the filter housing 10 and governs the overall radio-frequency and transmission characteristic of the individual cavity and of the respective filter. The dielectric resonator element 44 is part of a compact tuning unit 40 that is associated with each cavity (Figures 8-10). The tuning unit 40 is screwed onto the robust motor mounting plate 13 from above and has a fixed holder 46 (Figure 10), to ~~whose~~ end of which the dielectric resonator element 44 is attached, which projects

through a (circular) opening 25 (Figure 1), which is associated with the cavity, into the cavity located underneath.

The dielectric resonator element 44 has a central circular through-hole 58 and an eccentrically arranged circular cutout 59 (Figure 12). A dielectric body 45 (Figure 13) of the same thickness is mounted in the eccentric cutout 59 such that it can rotate about a rotation axis 60 that is at right angles to the disk plane of the dielectric resonator element 44. The cutout 59 is in the form of a circular-cylindrical through-hole that is concentric about the rotation axis 60. The external dimensions of the dielectric body 45 are matched to the cutout 59 in such a way that the two are separated from one another only by narrow air gaps. For this purpose, the dielectric body 45 is bounded in a first direction (which is at right angles to the rotation axis 60) by two parallel, planar surfaces 61, 62, and is bounded in a second direction (which is at right angles to the rotation axis 60 and to the first direction) by two cylindrical envelope surfaces 63, 64, which are concentric about the rotation axis 60 (see Figure 13; the body 45 inserted into the cutout can be seen in Figure 9).

The dielectric body 45 is preferably formed from the same dielectric material as the dielectric resonator element 44. It is attached to the end of a holder 47 (Figure 10) which is mounted such that it can rotate, and can be rotated by means of the mechanism that is accommodated in the tuning unit 40 relative to the dielectric resonator element 44, about the rotation axis 60. The rotation allows the resonant frequency of the resonator element, and thus the mid-frequency of the filter, to be varied.

The tuning unit 40 (Figures 8-10) essentially comprises a

gearbox unit 42 and a motor 41, which is flange-connected to the gearbox unit 42 (see Figure 10) at the side and drives the holder 47 (which can rotate) via the gearbox unit 42. The motor 41 is preferably a stepping motor. As can be seen from Figure 10, the gearbox unit 42 has a housing 43 on whose lower face the holder 46 for the stationary dielectric resonator element 44 is mounted. A rotating element 49 in the form of a shaft is mounted by means of a precision bearing 48 such that it can rotate in a through-hole which passes through the base of the housing 43 at right angles, and this rotating element 49 is firmly connected to the holder 47 that can rotate. By way of example, a special bearing which can be prestressed, is provided with two ball bearings and is used in hard disk memories of PCs is used as the precision bearing 48. Bearings ~~such as these~~of this type can be obtained, for example, using the name “RO bearing” (after the inventor Rikuro Obara from the Japanese Company Minebea Co, Ltd. Their principle is described inter alia, in ~~US A~~ US PATENT NO. 5,556,209. The precision bearing 48 contributes to the achievement of a positioning accuracy of the dielectric body 45 in the region of a few micrometers, as is required for accurate tuning of the filters F1, F2 and F3.

A gearwheel 51 in the form of a circle sector is mounted on the rotating element 49, as shown in Figure 11. Since the full tuning range of the configuration shown in Figure 9 and comprises the dielectric resonator element 44 and the dielectric body 45 can be covered by rotation of the body through 90° from the position shown in Figure 9, a sector angle of 100° is more than adequate for the gearwheel 51. Designing the gearwheel 51 to be in the form of a circle sector means that the gearbox unit 42 and thus the tuning unit 40 can be designed to be extremely compact~~.~~

The worm gear on a driveshaft 55 (Figure 10), which is at right angles to the rotation axis 60 and is connected directly to the motor 41, engages with the gearwheel 51. In order to ensure that there is no play in the engagement between the worm gear and the gearwheel 51, the rotating element is prestressed in the rotation direction by means of a spiral spring 50, which is mounted on the housing 43. Two light barriers 52 and 53 are provided in the gearbox unit 42, in order to control the drive unit 40. The first light barrier 52 scans a marking element (not shown in Figure 10) which is in the form of a rod, is seated in an appropriate mounting hole 56, 57 in the gearwheel 51 (Figure 11) and marks the end points of the pivoting range. The second light barrier 53 scans a position sensor disk 54, which is seated on the driveshaft 55 and is provided with a radial slot. The interaction of the two light barriers allows the initial or zero position of the gearwheel 51, and thus the initial position of the dielectric body 45, to be determined precisely.

As already mentioned further above, the four cavities 21,..,24 with the dielectric resonator elements 44 and bodies 45 placed centrally in them are arranged in a square in each of the filters F1,..,F3. This is illustrated once again in Figure 14 on the basis of the example of the filter F3. The RF energy is injected into the first cavity 21, propagates by means of the coupling slots 35 via the adjacent cavities 22, 23 and 24, and is emitted again from the last cavity 24. The coupling slots 35 are located on the vertical center planes or in the center of separating walls of the cavities 21,..,24. The dielectric resonator elements 44 are rotated together with their eccentric cutouts 59 from the vertical center plane of the coupling slot 35 that is located closest to the cutout through a predetermined angle which, in the example, is about 57°.

This particular configuration of the cutout and coupling slot results in the filter having a radio-frequency response in which the coupling factor decreases as the frequency increases, when the dielectric body 45 is rotated toward the next coupling slot. An additional degree of freedom is provided by the capability for additional coupling between the first cavity 21 and the last cavity 24, as is indicated by the S-shaped coupling element in Figure 14.

Another configuration of a filter F′ by means of which - apart from the transverse coupling - the same effect can be achieved is for the cavities 21,..,24 to be arranged ~~in a few,~~ as shown in Figure 15. In this case as well, the coupling slots 35 are arranged centrally, and the dielectric resonator elements 44 are rotated, together with their cutouts, through about 60° from the center plane.

A control system is provided for tuning of the filter arrangement by means of the tuning elements 40, and a highly simplified block diagram of this control system is illustrated in Figure 16. The controller 65 has a control block 66 which, for example, has a suitable microprocessor and a number of power outputs corresponding to the number of motors 41. The control block 66 controls the stepping motors 45 via the power outputs, and is activated from the outside via an input unit 68. The control block 66 interacts with a memory (EPROM) 67, in which value tables are stored, which associate a specific step number of the stepping motors 41 with a number of selected frequency values of the filter. Intermediate values are produced by interpolation. Furthermore, the control block 66 receives signals from the two light barriers 52, 53 for each tuning unit 40. If a specific frequency for the filter or filters is intended to be set (during start-up), the dielectric

bodies 45 are first of all moved back to their initial position. The reaching of the initial position is signaled by appropriate signals from the two light barriers 52, 53. The stepping motors 41 are then switched forward from the initial position by the number of steps corresponding to the table value taken from the memory 67, or to a value determined by interpolation for the desired frequency. The motors 41 for a filter may in this case all be switched largely at the same time, or may be switched following a specific algorithm.

If the radio-frequency filter arrangement with the filter housing 10 according to the exemplary embodiment (Figure 1) is intended to be designed for band 4, that is to say for a tunable frequency range from about 4.4 GHz to 5 GHz, the housing (without the tuning units) has a base area of approximately 66 mm × 186 mm, and a height of approximately 30 mm. Each of the cavities has a base area (A1,..,A4 in Figure 7) of 28 mm × 28 mm, and a height of 20 mm. The dielectric resonator element 44 has a thickness of approximately 6 mm, an external diameter of approximately 15 mm, and an internal diameter of approximately 6.5 mm. The diameter of the eccentric cutout 59 is approximately 6 mm, the width of the dielectric body 45 between the parallel vertical boundary surfaces is approximately 3 mm. The tuning unit 40 projects only approximately 24 mm beyond the surface of the motor mounting plate 13.

Characteristic curves as are shown in Figures 18 to 20 are obtained for a filter arrangement designed in this way:

Figure 18 shows the relationship between the tunable filter frequency and the rotation angle of the dielectric body 45 in the eccentric cutout 59 in the dielectric resonator element 44. The rotation angle range is from 0° to 90°. At

0° the straight sides of the dielectric body 45 are tangential with respect to the dielectric resonator elements 44.

Figure 19 shows the measured curves for a number of S parameters of the filters according to the exemplary embodiment, specifically the reflection coefficient at the input S11 (curve B), the transmission coefficient in the forward direction, S21 (curve A), as a function of the frequency for a selected mid-frequency of 4.7 GHz. The frequency range is in this case ± 15 MHz about the respective mid-frequency. The graph is logarithmic. The scale in the vertical direction is 0.5 dB per division for S21, and 5 dB per division for S11.

Figure 20 shows the measured curve for S21 for 4.7 GHz over an extended frequency range of ± 60 MHz about the respective mid-frequency. The graph is logarithmic. In this case, the scale in the vertical direction is 10 dB per division.

Overall, the invention provides a tunable radio-frequency filter arrangement which can be designed such that it is simple and costs little, can be tuned very accurately and reproducibly over a wide frequency range, is extremely ~~space saving~~compact, and is distinguished by very good radio-frequency characteristics. In particular, a number of identical filters can be accommodated in a common filter housing, with little additional complexity.

List of reference symbols

10	Filter housing (Filter box)
11	Base plate
12, 20	Wall plate (transverse)
13	Motor mounting plate
14, 32	Wall plate (longitudinal)
15,..,19	Separating plate (transverse)
21,..,24	Cavity
25	Opening (Circuit)
26,28,30	Input (Filters F1, F2, F3)
27,29,31	Output (Filters F1, F2, F3)
33	Separating plate (longitudinal)
34, 36, 37, 38	Crossing slot
39	Mounting slot
35	Coupling slot
40	Tuning unit
41	Motor (stepping motor)
42	Gearbox unit
43	Housing (Gearbox unit)
44	Dielectric resonator element (stationary)
45	Dielectric body (moving)
46	Holder (in the form of a half shell)
47	Holder (which can rotate)
48	Precision bearing
49	Rotating element
50	Spiral spring
51	Gearwheel (in the form of a circle segment)
52, 53	Light barrier
54	Position sensor disk
55	Drive shaft (with worm gear)
56, 57	Attachment hole (position sensor pin)
58	Central through-hole

59	Eccentric cutout
60	Rotation axis
61,..,64	Boundary surface
65	Controller
66	Control block
67	Memory (EPROM)
68	Input unit
69	Metal sheet
A1,..A4	Surface
F,F1,F2,F3	Filter (Bandpass filter)
K1, K2	Curve
L1, L2	Mounting lug